36. (Amended) The rear projection display device according to claim 27, wherein an angle of a maximum value j-max and a minimum value j-min is formed by a normal of a front surface of the screen and a principal ray of the image light irradiated on the front surface of the screen, and an angle β is obtained when the reflectivity of light, having a polarization direction parallel to the plane including the image light irradiated on the front surface of the screen and the normal of the front surface of the screen, to the front surface of the screen is at a minimum.

REMARKS

The Office Action dated December 8, 2000, has been received and carefully noted. The period for response having been extended from March 8, 2001, until June 8, 2001, by the attached Petition for Extension of Time, the amendments made herein and following remarks are submitted as a full and complete response thereto.

Claims 11, 24 and 36 have been amended. Figures 9 and 10 have been labeled as --Prior Art--. A substitute specification in proper idiomatic English is respectfully submitted for consideration. No new matter has been added by the amendments made herein. Thus, claims 1-38 are respectfully submitted for consideration.

The drawings were objected to under 35 C.F.R. §1.83(a) because Figs. 9 and 10 were not labeled as --Prior Art--, and that the drawings fail to show the limitation of j-min<β<j-max recited in the claims. Applicants appreciate the Examiner's courtesy in highlighting these deficiencies. Attached is a Request for Approval of Drawings Corrections with proposed changes to Figs. 9 and 10, highlighted in red. Changes to

Figs. 9 and 10 are respectfully submitted for consideration. Upon approval of this request, formal drawings will be timely filed.

In addition, Applicants have amended claims 11, 24 and 36 which deleted the limitation of j-min<β<j-max from each of these claims. It is respectfully submitted that the deletion of the above limitation overcomes the objection of the drawings under 35 C.F.R. §1.83(a), and Applicants respectfully request that the objection be withdrawn. It is further submitted that the amendments made to these claims do not narrow the scope of the claims.

The specification was objected to because it was not in proper idiomatic English. Applicants respectfully submit a substitute specification in proper idiomatic English which fully complies with 37 C.F.R. §1.52(a) and (b). Also attached is a marked-up copy of the original specification. It is respectfully submitted that the substitute specification submitted herewith does not contain any new matter. Therefore, Applicants respectfully submit the substitute specification for consideration.

Claims 11, 24 and 36 were rejected under 35 U.S.C. §112, second paragraph, as being indefinite. In making this rejection, the Office Action took the position that the limitations recited in these claims are unclear. Applicants respectfully submit that the amendments made to these claims should be sufficient to overcome the deficiencies noted in the Office Action and place these claims in compliance with U.S. patent practice. Furthermore, Applicants respectfully refer to pages 25-28 of the specification, and Figs. 5 and 7 of the drawings in explaining each and every limitation recited in claims 11, 24 and 36. Specifically, Applicants refer to page 1 of the specification

wherein a coordinate system is disclosed where a horizontal direction of a rectangular screen 170 is taken along an x-axis, a vertical direction of the screen 170 is taken along a y-access, and a perpendicular direction of the screen 170 is taken along a z-axis. The coordinate system is also clearly illustrated on Figs. 1-5 of the drawings. Therefore, Applicants respectfully request that the rejection under 35 U.S.C., §112, second paragraph, be withdrawn.

Claims 1-4, 6-7, 13-17, 19-20, 26-29, 31-32 and 38 were rejected under 35 U.S.C. §102(b), as being anticipated by Shikama (U.S. Patent No. 5,285,287). Applicants respectfully traverse this rejection, and submit that each of these claims recites subject matter which is neither disclosed nor suggested in the prior art.

Claim 1, upon which claims 2-13 are dependent, recites a rear projection display device comprising a light source lamp, a color splitting means for splitting light emitted from the light source lamp into a plurality of color components, and a plurality of liquid crystal panels for optically modulating each color light split by the color splitting means. The rear projection display device further comprises a color synthesizing means for synthesizing each of the color light modulated by the liquid crystal panels, and a projection means for projecting image light which is color-synthesized by the color synthesizing means on a screen from slantly above or from slantly below. The polarization direction of at least one color component out of the image light irradiated onto the screen is parallel to a vertical cross section of the screen.

Claim 14, upon which claims 15-26 are dependent, recites a rear projection device similar to the device recited in claim 1 with the exception that the projection means for projecting image light is color-synthesized by the color synthesizing means

on a screen from a slant side. Also, the polarization direction of at least one color component out of the image light irradiated on the screen is parallel to a horizontal cross section of the screen.

Claim 27, upon which claims 28-38 are dependent, recites a rear projection display device similar to the display device recited in claim 1 with the exception that the projection means slantly projects image light which is color-synthesized by the color synthesizing means on a screen. The polarization direction of at least one color component out of the image light irradiated on the screen is parallel to a plane including the image light irradiated on the screen in a normal of the screen.

Accordingly, the present invention is directed to a rear projection display device which enables an observer to observe a picture on the front surface of a screen by projecting image light onto the back surface of the screen from a slant. Furthermore, the present invention provides a rear projection device capable of improving the brightness and the image quality of the picture by improving the utilization efficiency of the image light which is projected onto the screen from a slanted angle.

It is respectfully submitted that the prior art fails to disclose or suggest the elements of the presently pending claims, and therefore, fails to provide the advantages which are provided by the present invention.

Shikama discloses a projector 300 comprising a light source 1 with lamp 120 and parabolic mirror 130 that directs white light toward dichroic mirrors 14B and 14G. The projector 300 also comprises mirrors 11a, 11b and 11c, liquid crystal display panels 3R, 3G and 3B, a dichroic prism 15, a projection lens 4, and a reflecting, front projection screen 5F. The lamp 120 is at the focal point of the parabolic mirror 130 to produce a

collimated beam of white light. The dichroic mirror 14B transmits red and green light, but reflects blue light. The dichroic mirror 14G reflects green light but transmits red light. By means of the dichroic mirrors 14B and 14G, white light 2 is decomposed into three primary colors. The mirrors 11A and 11B reflect red light, the dichroic mirror 14B and the mirror 11C reflect blue light, and the dichroic mirror 14G reflects green light. The reflected light is directed to the respective one of the liquid crystal display panel 3R, 3G and 3B, each of which produces a monochromatic image of the respective color under control of an operating circuit.

Upon review and consideration of Shikama, Applicants respectfully submit that each and every element recited within claims 1, 14 and 27 of the present application is neither disclosed nor suggested by the cited prior art. In particular, Applicants respectfully submit that the rear projection display device claimed in the present application is clearly distinct from that which is illustrated in Shikama. Specifically, Applicants respectfully submit that Shikama fails to disclose or suggest a polarization direction of at least one color component out of the image light irradiated on the screen that is parallel to a vertical cross section of the screen, or is parallel to a horizontal cross section of the screen, or is parallel to a plane including the image light irradiated on the screen and a normal of the screen. Although Shikama discloses a projecting method for a picture display apparatus having three crystal panels and a dichrolic prism, Applicants respectfully submit that Shikama nevertheless fails to disclose or suggest that the polarization directions of the red, green and blue primary color lights emitted from each of the liquid crystal panels are adjusted in correlation to the fresnel lens screen as disclosed in the present invention. Accordingly, Applicants respectfully

submit that Shikama fails to disclose or suggest each and every element recited in claims 1, 14 and 27 of the present application.

As for claims 2-4, 6-7, 13, 15-17, 19-20, 26, 28-29, 31-32 and 38, Applicants submit that each of these claims recites subject matter which is neither disclosed nor suggested by Shikama. In particular, each of these dependent claims depends from independent claims 1, 14 and 27, respectively. Therefore, each of these dependent claims incorporates each and every limitation recited within independent claims 1, 14 and 27, therein, respectively. Therefore, Applicants submit that each of claims 2-4, 6-7, 13, 15-17, 19-20, 26, 28-29, 31-32, and 38, also recites subject matter which is neither disclosed nor suggested by Shikama for at least the reasons set forth above with respect to claims 1, 14 and 27.

Claims 5, 8, 18, 21, 30 and 33 were rejected under 35 U.S.C. §103(a) as being unpatentable over Shikama in view of Soref et al. (U.S. Patent No. 4,516,837). In making this rejection, the Office Action took the position that Shikama disclosed each and every element recited in the claimed invention with the exception of showing a retardation plate. Soref was cited for curing the deficiencies which exist in Shikama. Applicants respectfully traverse this rejection, and submit that each of claims 5, 8, 18, 21, 30 and 33 recites subject matter that is neither disclosed nor suggested in the cited prior art.

Soref discloses an electrically-control device employing optically active nematic liquid crystals for switching polarized or unpolarized optical signals with low insertion loss. Figure 1 of Soref illustrates a PBS cube 11 with the addition of a reflecting prism 20 and a half-wave retardation plate 21. The half-wave retardation plate 21 is a

polarization form converter. It is an optical element with two principal axis, slow and fast, that resolves an incident beam into two orthogonally polarized components, without appreciably altering the intensity or degree of polarization.

Upon review and consideration of the combination of Shikama and Soref, Applicants respectfully submit that each and every element recited within each of claims 5, 8, 18, 21, 30 and 33, is neither disclosed nor suggested by Shikama, and/or Soref, alone or in combination. In particular, each of claims 5 and 8, 18 and 21, 30 and 33, depends from independent claims 1, 14 and 27, respectively, and therefore, each and every limitation recited within the independent claims, is also recited within dependent claims 5 and 8, 18 and 21, and 33. As such, these dependent claims incorporate the limitation of a polarization direction of at least one color component out of the image light irradiated onto the screen, and is parallel to a vertical cross-section of the screen, or is parallel to a horizontal cross-section of the screen, or is parallel to a plane, including the image light irradiated on the screen and a normal of the screen, respectively. Upon review of Soref, it is respectfully submitted that Soref fails to disclose and suggest the elements above, and therefore, fails to cure the deficiencies which exist in Shikama. Thus, Applicants respectfully that neither Shikama nor Soref, alone or in combination, disclose or suggest each and every element recited within claims 5, 8, 18, 21, 30 and 33 of the present application.

In view of the above, Applicants respectfully submit that claims 1-38, each recites subject matter that is neither disclosed nor suggested in the cited prior art. Applicants also submit that the differences between the subject matter and the prior art relied upon, is more than sufficient to render claims non-obvious to a person of ordinary skill in the

art, and therefore, respectfully request that claims 1-38 be found allowable, and this application be passed to issue.

If, for any reason, the Examiner determines that the application is not now in condition for allowance, it is respectfully requested that the Examiner contact by telephone the Applicants' undersigned attorney at the indicated telephone number to arrange for an interview to expedite the disposition of this application.

In the event this paper is not being timely filed, the Applicants respectfully petition for an appropriate Extension of Time. Any fees for such an extension, together with any additional fees, may be charged to counsel's Deposit Account Number 01-2300.

Respectfully submitted,

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SH/pwc

Enclosures:
- Petition for Extension of Time (3 months)
- Request for Approval of Drawing Corrections (Figs. 9 and 10)
- Substitute Specification
- Marked-Up Copy of Original Specification
- Associate Power of Attorney

Marked-Up Copy of Original Claims

11. (Amended) The rear projection display device according to claim 1, wherein [the relation j-min< β <j-max is satisfied, where] an angle of a maximum value j-max and a minimum value j-min is formed by a normal of a front surface of the screen and a principal ray of the image light irradiated on the front surface of the screen, and an angle β is obtained when the reflectivity of light, having a polarization direction parallel to the vertical cross section of the screen, to the front surface of the screen is at a minimum.

24. (Amended) The rear projection display device according to claim 14, wherein [the relation j-min<j-max is satisfied, where] an angle of a maximum value j-max and a minimum value j-min is formed by a normal of a front surface of the screen and a principal ray of the image light irradiated on the front surface of the screen, and an angle β is obtained when the reflectivity of light, having a polarization direction parallel to the horizontal cross section of the screen, to a front surface of the screen is at a minimum.

36. (Amended) The rear projection display device according to claim 27, wherein [the relation j-min < β <j -max is satisfied, where] an angle of a maximum value j-max and a minimum value j-min is formed by a normal of a front surface of the screen and a principal ray of the image light irradiated on the front surface of the screen, and an angle β is obtained when the reflectivity of light, having a polarization direction parallel to the plane including the image light irradiated on the front surface of the screen and the normal of the front surface of the screen, to the front surface of the screen is at a minimum.

Marked-Up Copy of Original Specification part of paper #11

TITLE OF THE INVENTION

Rear Projection Display Device

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a rear projection display device which enables [for enabling] an observer to observe a picture on a front surface of a screen by [slantly] slanting projecting image light on to a back surface of a [the] screen.

Description of the Prior Art

Figs. 9, 10 illustrate one example of a conventional rear projection display device. Specifically, Fig. 9 [is] illustrates a cross sectional view [schematically illustrating a structure] of a conventional rear projection display device, and Fig. 10 [is] illustrates a top plan view [schematically illustrating a structure of a projection unit] of the rear projection display device [of] shown in Fig. 9. In the following description, a coordinate system is used where a horizontal direction of a rectangle screen 170 is taken along an x- axis, a vertical direction of the screen 170 is taken along a y-axis, and a perpendicular direction to the screen 170 is taken along a z-axis.

[As shown in Fig. 9, the] The rear projection display device of Fig. 9 includes: a projection unit 120 arranged in a body 110[. A]; a projection lens 130 [is] arranged on a light emitting opening of the projection unit 120[. A]; a reflecting mirror 160 [is] arranged on an inner back surface of the body 110[,]; and a transmission type diffusing screen 170 [is] arranged on the front of the body 110. Image light which is magnified and projected from the projection unit 120 through the

projection lens 130, is reflected on the reflecting mirror 160, and is irradiated onto a back surface of the diffusing screen 170, and then a A picture is observed on the front surface of the diffusing screen 170.

As shown in Fig. 10, the projection unit 120 includes a white light source 121 comprising a lamp 121a and a reflector 121b. Dichroic mirrors 122, 123 split the white light emitted from the white light source 121 into light of three colors of light. A first dichroic mirror 122 selectively reflects light of a red component (referred as "red light" hereinafter) out of the white light emitted from the lamp 121a and transmits the light of the other color components. A second dichroic mirror 123 selectively reflects light of a green component (referred as "green light" hereinafter). The green Green light out of the light which is transmitted through the first dichroic mirror 122 is selectively reflected on the second dichroic mirror 123 and is introduced to a liquid crystal panel 127g for green. Light of a blue component (referred as "blue light" hereinafter), out of the light transmitted through the second dichroic mirror 123, is introduced to a liquid crystal panel 127b for the blue light by reflecting mirrors 125, 126. The red light reflected on the first dichroic mirror 122 is introduced to a liquid crystal panel 127r for red by the first reflecting mirror 124.

The color lights are Color light respectively modulated at the liquid crystal panels 127r, 127g, and 127b respectively, and are is synthesized at a dichroic prism 128 and subsequently is emitted to the projection lens 130.

Incident directions of the color lights light modulated at the liquid crystal panels

127r, 127g, and 127b to the dichroic prism 128 ~~is~~ are set with the consideration of color reproducibility at the dichroic prism 128. Light reflected on the dichroic prism 128 is S-polarized light, and light transmitted through the dichroic prism 128 is P-polarized light.

The S-polarized light is a linearly polarized light ~~which~~, wherein the oscillation direction of the electric vector of the light incident to a sample surface, is vertical to ~~a surface including~~ a normal ~~of the~~ sample surface and a normal ~~of~~ wave surface ~~which is a light traveling direction~~. The P-polarized light is a linearly polarized light ~~which~~, wherein the oscillation direction of the electric vector of the light incident to a sample surface, is included in an incident surface (a surface including a normal of the sample surface and a light traveling direction).

Specifically, the red light out of the light incident to the dichroic prism 128 is set to be S-polarized to a bonded surface 128x. A polarized light component, which is perpendicular to an x-z plane, is reflected on the bonded surface 128x. The green light is set to be P-polarized light to the bonded surfaces 128x, 128y. A polarized light component, which is parallel to the x-z plane, is transmitted through the bonded surface 128x, 128y. The blue light is set to be S-polarized light to the bonded surface 128y. A polarized light component, which is perpendicular to the x-z plane, is reflected on the bonded surface 128y. And then the red, green, and blue light is color-synthesized.

The color-synthesized image light is irradiated from the projection lens 130 to the back surface of the screen 170 through the reflecting mirror 160.

Recently, a rear projection display device capable of slantly irradiating image light to the screen 170 for reducing the depth of the device has been was proposed. When the above mentioned projection unit 120 is was used for slantly projecting image, a polarization direction of the projected image light to the screen 170 is was set in the direction orthogonal with the polarization direction of the image light to the dichroic prism 128. The red light is was P-polarized, the green light is was S-polarized, and the blue light is was P-polarized.

When the image light is slantly was projected to to the screen 170 on a slant, the light is was incident to the acrylic resin from an air with a certain angle of incidence out of a vertical incidence. Fig. 6 is a table showing the reflectivity characteristic characteristics of light incident to the acrylic resin from the air. As shown in Fig. 6, when the image light is slantly was projected on to the screen 170 on a slant, the reflectivity of P-polarized light to the screen 170 is was lowered while the reflectivity of S-polarized light to the screen 170 increases increased.

Fig. 8 presents the spectral luminous efficiency characteristics of a man. As shown in Fig. 8, the spectral luminous efficiency of a man's eyes is the highest at around a wavelength of 555nm which corresponds to a color of green, and therefore, a man is more likely to recognize green light being brighter in comparison with red and blue light.

As a result, when the image light is slantly was projected by using the conventional projection unit 120, the reflectivity of the brightest green light at

the screen 120 increases, and the brightness as a whole is lowered, and furthermore the image quality is degraded because of the reflected light.

Furthermore,

SUMMARY OF THE INVENTION

problems

The present invention was made to solve the above problem and has an objective to provide a rear projection display device capable of improving brightness and image quality by improving the utilization efficiency of image light which is slantly projected on a screen.

by providing — through the use — efficient — that — to — on a slant.

A rear projection display device of this invention comprises a light source lamp, color splitting means for splitting light emitted from the light source lamp into a plurality of color components, a plurality of liquid crystal panels for optically modulating each color light split by the color splitting means, color synthesizing means for synthesizing each of the color light modulated by the liquid crystal panels, and projection means for projecting image light which is color-synthesized by the color synthesizing means on a screen from slantly above or from slantly below. A polarization direction of at least a green component out of the image light irradiated on the screen is parallel to a vertical cross section of the screen.

on — either — slanting — slanting

When image light is projected to a screen from slantly above or from slantly below, an angle formed by a principal ray of light incident to the screen and a normal of the screen is larger in a vertical direction than in a horizontal direction. Therefore, when a polarization direction of a green component, of which spectral luminous efficiency for man's eyes is high, is made parallel to

is — a

a vertical cross section of the screen, less image light is reflected and lost on a back surface of the screen.

Specifically, A polarization direction adjusting means is provided for adjusting a polarization direction of at least the green component out of the image light, synthesized by the color synthesizing means, so that the polarization direction of at least the green component is parallel to the vertical cross section of the screen.

This structure ensures that a polarization direction of the green component out of the image light synthesized by the color synthesizing means is adjusted so as to be parallel to a vertical cross section of the screen when the polarization direction of the green light is not parallel to the vertical cross section.

It is preferred that the polarization directions of all the color components of the image light that are irradiated on the screen, are parallel to the vertical cross section of the screen.

Specifically, A polarization direction adjusting means is also provided for selectively adjusting a color component, of which a polarization direction is orthogonal with the vertical cross section of the screen, out of the image light synthesized by the color synthesizing means, so that the polarization direction of the color component is parallel to the vertical cross section of the screen.

This structure ensures that a color component having a polarization direction orthogonal [with] to a vertical cross section of the screen, [out of the image light synthesized by the color synthesizing means] is selectively adjusted so that the polarization direction is parallel to the vertical cross section of the screen.

A rear projection display device of this invention comprises a light source lamp, color splitting means for splitting light emitted from the light source lamp into a plurality of color components, a plurality of liquid crystal panels for optically modulating each color light split by the color splitting means, color synthesizing means for synthesizing each of the color light modulated by the liquid crystal panels, and projection means for projecting image light which is color-synthesized by the color synthesizing means on a screen from a slant side. A polarization direction of at least a green component out of the image light irradiated on the screen is parallel to a horizontal cross section of the screen.

When image light is projected on to a screen [from] on a slant [side], an angle is formed by a principal ray of light incident to the screen and a normal of the screen is larger in a horizontal direction than in a vertical direction. Therefore, when a polarization direction of a green component, of which spectral luminous efficiency for a man's eyes is high, is made parallel to a horizontal cross section of the screen, less image light is reflected and lost on a back surface of the screen.

[Specifically,] A polarization direction adjusting means is provided for adjusting a

polarization direction of at least the green component out of the image light irradiated on the screen so that the polarization direction of at least the green component is parallel to the horizontal cross section of the screen.

This structure ensures that a polarization direction of the green component out of the image light synthesized by the color synthesizing means, is adjusted so as to be parallel to a horizontal cross section of the screen even when the polarization direction of the green light is not parallel to the horizontal cross section.

It is preferred that the polarization directions of all the color components of the image light irradiated on the screen are parallel to the horizontal cross section of the screen.

Specifically, A polarization direction adjusting means is provided for selectively adjusting a color component, of which polarization direction is orthogonal with the horizontal cross section of the screen, out of the image light synthesized by the color synthesizing means so that the polarization direction of the color component is parallel to the horizontal cross section of the screen.

This structure ensures that a polarization direction of a color component out of the image light synthesized by the color synthesizing means is selectively adjusted so as to be parallel to a horizontal cross section of the screen.

A rear projection display device of this invention comprises a light source lamp, color splitting means for splitting light emitted from the light source lamp into a plurality of color components, a plurality of liquid crystal panels for optically modulating the light of each color split by the color splitting means, color synthesizing means for synthesizing each of the color light modulated by the liquid crystal panels, and projection means for slantly projecting image light which is color-synthesized by the color synthesizing means on a screen. A polarization direction of at least a green component out of the image light irradiated on the screen is parallel to a plane including the image light irradiated on the screen and a normal of the screen.

When image light is slantly projected on to a screen on a slant, an angle is formed by a principal ray of light incident to the screen and a normal of the screen is maximum in a plane including the image light irradiated on the screen and a normal of the screen. Therefore, when a polarization direction of a green component, of which spectral luminous efficiency for a man's eyes is high, is made parallel to the plane including the image light irradiated on the screen and a normal of the screen, less image light is reflected and lost on a back surface of the screen.

Specifically, A polarization direction adjusting means is provided for adjusting a polarization direction of at least the green component out of the image light irradiated on the screen so that the polarization direction of at least the green component is parallel to the plane including which includes the image light irradiated on the screen and the normal of the screen.

This structure ensures that a polarization direction of the green component out of the image light synthesized by the color synthesizing means is adjusted so as to be parallel to a plane including which includes the image light irradiated on the screen and a normal of the screen by the polarization direction adjusting means even when the polarization direction of the green light is not parallel to the plane including which includes the image light irradiated on the screen and a normal of the screen.

It is preferred that the polarization directions of all the color components of the image light irradiated on the screen are parallel to the a plane including which includes the image light irradiated on the screen and a normal of the screen.

Specifically A polarization direction adjusting means is provided for selectively adjusting a color component, of which a polarization direction is orthogonal with the plane including the image light irradiated on the screen and the normal of the screen, out of the image light synthesized by the color synthesizing means so that the polarization direction of the color component is parallel to the plane including the image light irradiated on the screen and a normal of the screen. The polarization direction is orthogonal with the plane which includes the image light irradiated on the screen and the normal screen.

This structure ensures that a color component of which a polarization direction is orthogonal with a plane including which includes image light irradiated on the screen and a normal of the screen out of the image light synthesized by the color synthesizing means, is selectively adjusted so that the color component

is made parallel to a plane [including], which includes the image light irradiated on the screen and the normal [of the] screen.

The polarization direction adjusting means comprises a retardation plate[.] and

[The], the projection means includes a plurality of aspherical mirrors functioning as a lens.

In a rear projection display device of this invention which image light is irradiated to the back surface of the screen from slantly behind or slantly above and a picture is observed on a front surface of the screen, the relation i-min< α <i-max is satisfied, where an angle of a maximum value i-max and a minimum value i-min is formed by a normal of a back surface of the screen and a principal ray of the image light irradiated on the back surface of the screen, and an angle α is obtained when the reflectivity of light, having a polarization direction parallel to the vertical cross section of the screen, to the back surface of the screen is minimum.

In this structure, light having a polarization direction parallel to a vertical cross section of a screen is irradiated on a back surface of the screen at an [angle including the] angle α at which the reflectivity to a normal [of a] back surface of the screen [at the back surface of the screen] is low.

In a rear projection display device of this invention, the relation j-min< β <j-max is satisfied, [where], wherein an angle of a maximum value (j-max) and a

minimum value (j-min) are formed by a normal of a front surface of the screen and by a principal ray of the image light irradiated on the front surface of the screen, and an angle β is obtained when the reflectivity of light, having a polarization direction parallel to the vertical cross section of the screen, to the front surface of the screen is at a minimum.

In this structure, light having a polarization direction parallel to a vertical cross section of a screen is irradiated on to a front surface of the screen at an angle including the angle β at which the reflectivity to a normal of a back surface of the screen at the back surface of the screen is low.

The screen includes a fresnel lens and the front surface of the screen is an inclined surface with a ring body shaped protrusion of the fresnel lens.

The polarization direction of at least the green component out of from the image light irradiated on the screen is parallel to the vertical cross section of the screen.

When a polarization direction of a green component, of which spectral luminous efficiency for man's eyes is high, is made parallel to a vertical cross section of the screen, less image light is reflected and lost on a back surface of the screen.

In a rear projection display device of this invention which image light is irradiated on to the back surface of the screen from a slant side and a picture is

from the side on a slant.

observed on a front surface of the screen, the relation relationship of $i\text{-}min < \alpha < i\text{-}max$ is satisfied, where an angle of a maximum value (i-max) and a minimum value (i-min) ~~of~~ is formed by a normal of a back surface of the screen and by a principal ray of the image light irradiated on the back surface of the screen. ~~and an~~ The angle α is obtained when the reflectivity of light, having a polarization direction parallel to the horizontal cross section of the screen, to the back surface of the screen is at a minimum.

In this structure, light having a polarization direction parallel to a horizontal cross section of a screen is irradiated on to a back surface of the screen at an angle including the angle α at which the reflectivity to a normal of a back surface of the screen at of the back surface of the screen is low.

In a rear projection display device of this invention, the relation $j\text{-}min < \beta < j\text{-}max$ is satisfied, where an angle of a maximum value (j-max) and a minimum value (j-min) is formed by a normal of a front surface of the screen and by a principal ray of the image light irradiated on the front surface of the screen. and an The angle β is obtained when the reflectivity of light, having a polarization direction parallel to the horizontal cross section of the screen, to the front surface of the screen is at a minimum.

In this structure, light having a polarization direction parallel to a horizontal cross section of a screen is irradiated on to a front surface of the screen at an angle including the angle β at which the reflectivity to a normal of a back surface of the screen at the of the back surface of the screen is low.

The screen includes a fresnel lens and the front surface of the screen is an inclined surface with a ring body shaped protrusion of the fresnel lens.

The polarization direction of at least the green component ~~out of~~ from the image light irradiated on to the screen is parallel to the horizontal cross section of the screen.

When a polarization direction of ~~a~~ the green component of which spectral luminous efficiency for man's eyes is high, is made parallel to a horizontal cross section of the screen, less image light is reflected and lost on ~~a~~ the back surface of the screen.

In a rear projection display device of this invention which image light is ~~slantly~~ irradiated on a slant to the back surface of the screen and where a picture is observed on a front surface of the screen, the ~~relation~~ relationship of i-min< α <i-max is satisfied. ~~where~~ an angle of a maximum value (i-max) and a minimum value (i-min) is formed by a normal ~~of a~~ back surface of the screen and by a principal ray of the image light irradiated on the back surface of the screen. ~~and an~~ The angle α is obtained when the reflectivity of light, having a polarization direction parallel to a plane including image light irradiated on the back surface of the screen and a normal of the back surface of the screen, to the back surface of the screen is at a minimum.

In this structure, light having a polarization direction parallel to the plane

including image light irradiated on to the back surface of the screen and a normal of the back surface of the screen is irradiated on to a back surface of the screen at an angle including the angle α at which the reflectivity to a normal of a back surface of the screen at the screen is low.

relationship of

In a rear projection display device of this invention, the relation j-min< β <j-max is satisfied, where an angle of a maximum value (j-max) and a minimum value (j-min) is formed by a normal of a front surface of the screen and by a principal ray of the image light irradiated on to the front surface of the screen. and an The angle β is obtained when the reflectivity of light, having a polarization direction parallel to the plane including image light irradiated on to the front surface of the screen and on to a normal of the front surface of the screen, to the front surface of the screen is minimum.

In this structure, light having a polarization direction parallel to a plane including image light irradiated on to the front surface of the screen and on to a normal of the front surface of the screen is irradiated on a front surface of the screen at an angle including the angle β at which the reflectivity to a normal of a front surface of the screen at the front surface of the screen is low.

The screen includes a fresnel lens and the front surface of the screen is an inclined surface with a ring body shaped protrusion of the fresnel lens.

The polarization direction of at least the green component out of from the image light irradiated on to the screen is parallel to a plane including image light

irradiated on the back surface of the screen and a normal of the back surface of the screen.

When a polarization direction of a green component of which spectral luminous efficiency for man's eyes is high is made parallel to a plane including image light irradiated on the front surface of the screen and a normal of the front surface of the screen, less image light is reflected and lost on a back surface of the screen.

BERIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross sectional view schematically illustrating a structure of a rear projection display device of one embodiment according to the present invention;

Fig.2 is a front elevation of the rear projection display device of Fig. 1;

Fig. 3 is a top plan view schematically illustrating a projection unit of the rear projection display device of Fig. 1;

Fig. 4 is a side view of the projection unit of Fig. 3;

Fig. 5 is an enlarged segmentary sectional view of a screen of the rear projection display device of Fig. 1;

Fig. 6 is a graph of the reflectivity characteristic of light incident to acrylic resin from the air;

Fig. 7 is a graph of the reflectivity characteristic of light emitted from the acrylic resin to the air;

Fig. 8 is a graph of spectral luminous efficiency characteristics of a man;

Fig. 9 is a cross sectional view schematically illustrating a structure of a

conventional rear projection display device;

Fig. 10 is a top plan view of a projection unit of the rear projection display device of Fig. 9.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when collected in conjunction with the accompanying drawings.

DESCRIPTION OF THE PREFFERED EMBODIMENT

Explanation is made on of one of the embodiments of a rear projection display device according to the present invention is made by referring to the drawings. In the following description, a coordinate system where a width direction of a rectanglar screen 7 is taken along an x-axis, a height direction of the screen 7 is taken along a y-axis, and a perpendicular direction to the screen 7 is taken along a z-axis.

In this embodiment, Figs. 1 is a cross sectional view of the rear projection display device, and Fig. 2 is a front elevation of the device. both schematically illustrate a structure of a rear projection display device. Figs. 3, 4 schematically illustrate a structure of a projection unit in the rear projection display device of Fig. 1, wherein; Fig. 3 is a top plan view, and Fig. 4 is a side view. Fig. 5 is an enlarged segmentary sectional view of a screen of the rear projection display device of Fig. 1. Fig. 6 is a graph of the reflectivity characteristic of light incident to acrylic resin from the air, and Fig. 7 is a graph of the reflectivity characteristic of light emitted from the acrylic resin to the

air[, and] Fig. 8 is a graph of spectral luminous efficiency characteristics of a man.

As shown in Fig. 1, a rear projection display device of this invention includes a projection unit 2 for producing image light, a screen 7 for forming a picture when the image light is projected thereon, [first-fourth] four mirrors 3-6 for introducing the image light emitted from the projection unit 2 to the screen 7, and a body 1 for [holding] housing these elements [incorporatively] therein.

An image forming system is composed of the first-third mirrors 3-5. The first mirror 3 has an aspherical concave shape, the second and third mirrors 4, 5 have aspherical convex shapes. The shapes of the mirrors in the image forming system ensure~~s~~ corrections of aberration, such as astigmatism, [and] coma, [of image light] and magnifications of the image light. The image light emitted from the projection unit 2 is successively reflected on the first-third mirrors 3-5, and is irradiated on the fourth mirror 6 which is arranged on [an] the internal back surface of the body 1. The image light irradiated on the fourth mirror 6, which is of a flat plate shape, is irradiated from slantly behind on a back surface of the screen 7 which is arranged on a front opening of the body 1[,]. [then a] A picture is thereby formed.

As shown in Fig. 3, the projection unit 2 is one of three-plate type. A light source 21 comprises a reflector 21b and a metal halide lamp 21a. White light emitted from the light source 21 is splited into [light of] three colors of light by dichroic mirrors 22, 23. The first dichroic mirror 22 selectively reflects red

light out of the white light emitted from the metal halide lamp 21a and transmits light of other color components. The second dichroic mirror 23 selectively reflects green light and transmits light of other color components.

The white light emitted from the metal halide lamp 21a is reflected on the reflector 21b. Then, ultra violet ray and infrared ray in the light are eliminated at an UV/IR filter (not shown), and the white light is irradiated to the first dichroic mirror 22 at an angle of 45° . Red light reflected on the first dichroic mirror 22 is introduced to the first liquid crystal panel for the red light 27r by the first reflecting mirror 24. The light transmitted through the first dichroic mirror 22 is irradiated on the second dichroic mirror 23 at an angle of 45° . Green light out of from the light transmitted through the first dichroic mirror 22 is selectively reflected on the second dichroic mirror 23 and is introduced to the second liquid crystal panel for the green light 27g. The Blue light, which is the rest of the light transmitted through the second dichroic mirror 23 is successively reflected on the second and third mirrors 25, 26, and is introduced to the third liquid crystal panel for the blue light 27b by the second and third reflecting mirrors 25, 26.

The red light introduced to the first liquid crystal panel for red 27r is optically modulated according to the image information of the red component, and is incident to the main surface 28r of the dichroic prism 28 for color synthesis. The green light introduced to the second liquid crystal panel for green 27g is optically modulated according to the image information of the green component, and is incident to the main surface 28g of the dichroic prism 28 for color synthesis. The blue light introduced to the first liquid crystal panel for blue

Similarly, the third

27b is optically modulated according to the image information of the blue component, and is incident to the main surface 28b of the dichroic prism 28 for color synthesis.

Light which is S-polarized to a bonded surface 28x out of the red light incident to the main surface 28r of the dichroic prism 28, that is a component of which polarization direction is vertical to the x-z plane, is reflected on the bonded surface 28x. Light which is P-polarized to the bonded surfaces 28x, 28y out of the green light incident to the main surface 28g of the dichroic prism 28, that is a component of which polarization direction is parallel to the x-z plane, transmits is transmitted to the bonded surfaces 28x, 28y. Light which is S-polarized to the bonded surface 28y of the blue light incident to the main surface 28b of the dichroic prism 28, that is a component of which polarization direction is vertical to the x-z plane, is reflected on the bonded surface 28y.

The color light optically modulated by each of the liquid crystal panel 27r, 27g, and 27b with correspondence corresponding to each color information is color-synthesized by the dichroic prism 28. The color-synthesized image light is emitted from the main surface 28c of the dichroic prism 28. The polarization directions of the light is respectively rotated by an angle of 90° at a $\lambda/2$ retardation plate 29, and the light is given to the image forming system.

The red light out of from the image light emitted from the main surface 28c of the dichroic prism 28 is S-polarized light to the bonded surface 28x, the green

light is P-polarized light to the bonded surfaces 28x, 28y, and the blue light is S-polarized light to the bonded surface 28y. The polarization directions are respectively rotated by an angle of 90° at the $\lambda/2$ retardation plate 29.[, then] Subsequently the red light is turned into P-polarized light to the bonded surface 28x, the green light is turned into S-polarized light to the bonded surfaces 28x, 28y, and the blue light is turned into P-polarized light to the bonded surface 28y.

As shown in Fig. 1, the image light transmitted through the $\lambda/2$ retardation plate 29 is successively reflected on the first-third mirrors 3-5 which compose the image forming system, and is irradiated to the fourth mirror 6 arranged on the back surface of the body 1. The shapes of the mirrors in the image forming system ensure corrections of aberration, such as astigmatism, [and] coma [of the image light], and [magnify] magnification of the image light.

The image light irradiated on the flat plate shaped fourth mirror 6 is irradiated to the back surface of the screen 7 from [slantly] a slant below the screen 7. The red light [out of] from the image light irradiated on the back surface of the screen 7 is S-polarized to the screen 7[, that is] wherein the polarization direction is vertical to the y-z plane. The green light is P-polarized to the screen 7[, that is] wherein the polarization direction is parallel to the y-z plane. Furthermore, The blue light is S-polarized to the screen 7[, that is] wherein the polarization direction is vertical to the y-z plane. The y-z plane is a vertical cross section of the screen 7.

As shown in Fig. 5, the screen 7 includes a fresnel lens screen 71 formed with acrylic resin and a lenticular lens screen 72. The image light reflected on to the

fourth mirror 6 is irradiated on a back surface 71a of the fresnel lens screen 71.

An angle (i) formed by a normal A to the back surface 71a of the fresnel lens screen 71 and a principal ray of the image light irradiated thereon is i-max at maximum at upper corners C1, C2 of the fresnel lens screen 71 (see Fig. 1), and is i-min at minimum at a lower corner C3 (see Fig. 1). In this embodiment, the first-fourth mirrors 3-6 are set so that i-max is to be 58.27° , and i-min is to be 32.27° .

Fig. 6 is a graph for showing the reflectivity characteristic of light incident to acrylic resin from the air. In this case, the refractivity of the air is 1.00, and the refractivity of the acrylic resin is 1.492. When the image light is slantly irradiated on a slant to the screen 7, it means that the light is incident at a certain angle of incidence from the air to the acrylic resin.

which forms

The reflectivity of light irradiated to the acrylic resin, forming the fresnel lens screen 71, from the air varies depending on an angle of incidence θ 1, an angle formed by the light irradiated to the acrylic resin and a normal of the acrylic resin at a point where the light is irradiated. As indicated by a The broken line in Figure 6 illustrates that this graph, regarding the reflectivity characteristic S of light of which polarization direction is vertical to a plane including light irradiated to the acrylic resin and the normal of the acrylic resin at a point where the light is irradiated, the reflectivity tends to increase as the angle θ 1 increases. On the other hand, as indicated by a the full line, regarding the reflectivity characteristic

The broken line in Fig. 6 pertains to

P of light of which polarization direction is parallel to a plane including light irradiated to the acrylic resin and the normal of the acrylic resin at a point where the light is irradiated as the angle θ 1 is close to the minimum value α the reflectivity reduces. The angle α of the minimum value is an angle when P-component of the reflected light is zero and the reflected light is a plane polarized light. Such the angle of incidence is referred as polarization angle. The polarization angle α is expressed by the expression 1 below where the refractivity at both ends of the boundary is defined as n1, n2.

The full line pertains to the reflectivity characteristic P of light of which polarization direction is parallel to a plane including light irradiated to the acrylic resin at a point where the light is irradiated.

【Expression 1】

$$\tan \alpha = n2 / n1$$

To be concrete, an angle α is approximately 56° according to the above expression when the light is incident to the acrylic resin from the air.

As indicated by a broken line of Fig. 6, the reflectivity to the screen 7 of the red light and blue light as S-polarized light out of the image light irradiated to the back surface 71a of the fresnel lens screen 71 is higher than the reflectivity of light irradiated parallel to the normal A of the screen 7, and the light utilization efficiency decreases. However, as indicated by a full line of Fig. 6, the reflectivity of the green light as P-polarized light to the screen 7 out of the image light irradiated on the back surface 71'a of the fresnel lens screen 71 is lower than the reflectivity of the light irradiated parallel to the normal A of the screen 7, and the light utilization efficiency increases.

It is known that the brightness a man recognizes is generally affected by green light as compared with red and blue light. A man feels light of the wavelength 555nm corresponding to the color of green the brightest (the visibility is high). Fig. 8 indicates the visibility of various wavelengths, taking the visibility at the wavelength 555nm corresponding to the green as the reference. When the visibility of the green is one, the visibility of the wavelength 630nm corresponding to the red is approximately 0.265, and the visibility of the wavelength 470nm corresponding to the blue is approximately 0.091.

As mentioned above, when the image light is slantly irradiated to the screen 7, the visibility of green light is remarkably higher than those of red and blue light. The lowered brightness caused by the S-polarized red and blue light to the screen 7 can be compensated by making the brightness of the P-polarized green light higher, and the brightness as a whole can be increased. In conjunction with the increased brightness, light reflected on the back surface 71a of the fresnel lens screen 71 decreases, and a ghost caused by the reflected light can be reduced, and thus the image quality can be improved. It is preferred that all the component of light be P-polarized light to the screen 7.

An angle (i) formed by a principal ray of the image light irradiated to the screen 7 and the normal A of the screen 7 is set to satisfy the below expression 2. Therefore, the utilization efficiency of P-polarized light component can be improved, leading to higher brightness.

【Expression 2】

$$i-min < \alpha < i-max$$

The image light transmitted through the back surface 71a of the fresnel lens screen 71 is refracted on the back surface 71a at an angle k1 corresponding to the Snel principle, and then is irradiated to a protruded inclined surface 71b formed in a ring body shape on an emitting side of the fresnel lens screen 71.

An angle of an inclined surface 71b is set so that an angle (j) formed by a normal B to the inclined surface 71b of the fresnel lens screen 71, and a principal ray of the image light irradiated to the screen 71 is j-max at maximum and j-min at minimum on each protruded inclined surface 71b of the fresnel lens screen 71. In this embodiment, an inclination τ of each inclined surface 71b is set so that j-max is to be 38.36° and j-min is to be 22.57°.

As shown in Fig. 7, the reflectivity of light emitted from the acrylic resin composing the fresnel lens 71 to the air varies depending on an angle θ2 which is formed by the light traveling in the acrylic resin and the normal of the acrylic resin at a point where the light is emitted. As indicated by a

in Fig. 7 illustrates that the reflectivity increases as ~~the~~ θ2 increases.

The broken line of this graph, regarding the reflectivity characteristic S of light of

The broken line also pertains to the

which polarization direction is vertical to a plane including the light traveling in the acrylic resin and the normal of the acrylic resin at a point where the

light is emitted, the reflectivity increases as the angle $\theta 2$ increases. On the other hand, as indicated by a full line, the reflectivity characteristic P' of light of which polarization direction is parallel to a plane including the light traveling in the acrylic resin and the normal of the acrylic resin at a point where the light is emitted, the reflectivity decreases as the angle $\theta 2$ is made close to the minimum polarization angle β. When the light is emitted from the acrylic resin to the air, the angle β is approximately 34° according to the expression 1.

The illustrates that the reflectivity decreases as the angle $\theta 2$ is made close to the minimum polarization angle β. The full line also pertains to the

As indicated by a broken line S' in Fig. 7, the reflectivity of the red and blue light, which is S-polarized to the screen 7 out of from the image light irradiated to the inclined surface 71b with a ring body shaped protrusion on an the emission side of the fresnel lens screen 71, is higher than the reflectivity of light irradiated in parallel to the normal B of the inclined surface 71b, and thereby lowering the light utilization efficiency is lowered. However, as indicated by the full line P' in Fig. 7, the reflectivity of the green light, which is P-polarized to the screen 7 out of from the image light irradiated to the inclined surface 71b, is lower than the reflectivity of light irradiated parallel to the normal B of the inclined surface 71b, and thereby increasing the light utilization efficiency increases.

As in the case that where the image light is irradiated on to the back surface 71a of the fresnel lens screen 71 from the air, the lowered brightness caused by the S-polarized red and blue light to the screen 7 is compensated by the increased brightness of the P-polarized green light to the screen 7, and thereby improving the brightness as a whole can be improved. Reflected light at the inclined surface

71b of the fresnel lens screen 71 is reduced reduces, and a ghost produced by the reflected light can also be reduced. Therefore, the image quality can be improved. It is preferred that all the color components be P-polarized light.

An angle (j) is formed by the principal ray of the image light irradiated on to the inclined surface 71b of the screen 7 and on to the normal B of the inclined surface 71b which satisfies the expression 3 below. Therefore, the light utilization efficiency of P-polarized light component itself can be improved, leading to higher brightness.

【Expression 3】

$j-min < \beta < j-max$

Image light is transmitted through the inclined surface 71b of the fresnel lens screen 7 and is refracted on to the inclined surface 71b at an angle k2 according to the Snel principle. and Thereafter, the image light is irradiated to the lenticular lens screen 72. Then, a picture is formed by the diffusing action of the lenticular lens screen 72.

In this embodiment, the image light is irradiated from slantly behind of the screen 7 on a slant. The image light may be irradiated from slantly the side of the screen 7 on a slant. In this case, the green light is adjusted so as to be P-polarized light to the screen 7, that is wherein the polarization direction is parallel to the x-z plane.

In this embodiment, the polarization direction of the green light is adjusted so as to be that it is parallel to the y-z plane. It is preferred that the polarization direction

be parallel to a plane including a principal ray of the image light and the normal of a part at a point where the image light is irradiated.

In this embodiment, the polarization direction of the green light is adjusted so that the light turns from S-polarized light into P-polarized light and is reflected to the screen 7 by the $\lambda/2$ retardation plate 29. In other case, a narrow band retardation plate may be used for selectively adjusting the polarization direction of the green light so that the light turns from S-polarized light into P-polarized light to the screen 7. In this case, polarization directions of the red and blue light do not change, and therefore, all the image light may be P-polarized light on to the screen 7.

In this embodiment, the image forming system is composed of the first-third mirrors 3-5. The same effect can be gained when using a lens system.

This invention can reduce reflection on a screen and can improve the brightness by making at least a the green component light P-polarized light on to a screen when image light is slantly irradiated to the screen on a slant. Furthermore, a ghost phenomenon caused by reflected light on the screen is prevented, and therefore, the image quality can be improved.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is and for example only and is not to be taken to be limiting. by way of limitation by way of illustration, the spirit and scope of the present invention being limited only by the terms of the appended claims.